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Original article

Pelvic dimensions and occurrence of dystocia in Black-and-White and Holstein-Friesian heifers

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Abstract

The Black-and-White (BW) breed, which until recently had dominated in Europe, was replaced by the Holstein-Friesian (HF) breed. As a result, the incidence of dystocia has increased. Dystocia occurs most frequently in heifers, and it is associated with high calf weight and/or too narrow pelvic openings in heifers. The aim of this study was to evaluate retrospectively the effects of pelvic dimensions and rump angle on calving ease in two cattle breeds. The research was carried out in four barns where BW and HF cattle were used. The course of parturition was evaluated in 317 heifers (BW, n=169; HF, n=148) based on direct observations. Calves were weighed, external and internal pelvic measurements were performed (using the Rice pelvimeter), and rump angle was determined in heifers. Based on the course of parturition, heifers of both breeds were divided into easy calving (EC) and difficult calving (DC) groups. The frequency of DC was 24.3% in HF heifers and 13.1% in BW heifers. In comparison with DC heifers, EC heifers had a larger pelvic area, in particular the internal dimensions of the bony pelvis, and a higher rump angle. In comparison with BW heifers, HF heifers had a smaller rump angle, a narrower pelvis and a lower ratio of pelvic area to calf weight. High dystocia rates in HF heifers could result from a relatively large fetus size and a less preferable pelvic size and rump angle. High variation in the internal pelvic dimensions in HF heifers indicates that the incidence of dystocia can be reduced through selection for a larger pelvic size and the optimal rump angle.

Keywords: dairy heifers, dystocia, intrapelvic area, pelvimeter, rump angle

Introduction

Dystocia continues to be an important issue in cattle herds. It is a major factor contributing to perinatal mortality, delays uterine involution, decreases reproductive performance and milk yields, and increases the costs of veterinary services, thus generating substantial economic losses (Gaafar et al. 2011). A failure in expulsive force, birth canal dilation, and/or fetal size and disposition may lead to dystocia (Mee 2008). Maternal, genetic and environmental risk factors for dystocia are associated with the development of the bony pelvis, the cow's hormonal profile, and the ability of the pelvic opening to expand during calving (Nahkur et al. 2011). Dystocia is most common among heifers, and its major causes are oversized fetus and/or inadequate size of the birth canal. In HF heifers, fetopelvic disproportion (FPD), i.e. the disproportion between fetal size and the

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pelvic size of the dam, is partly caused by reducing age at first calving (Mee 2008, Zaborski et al. 2009). Recent studies have investigated the relationships between external and internal pelvic dimensions vs. calving ease and calf mortality in dairy cattle. According to Nogalski (2003), increased dystocia incidence is related to a smaller pelvic aperture and increasing birth weight of calves. Calf body weight and the heifer's pelvic area are responsible for dystocia in 33% and 12%, respectively (Holm et al. 2014). The effect of breed on the risk of developing dystocia is associated with differences in the relative body weight, pelvic structure and dimensions in certain cattle breeds (Nogalski and Mordas 2012, Holm et al. 2014). Gundelach et al. (2009) described a relationship between external pelvic length and perinatal mortality. Due to significant differences in the anatomy of the female pelvis, both inter-species and inter-breeds, this problem has not gained enough attention to date (Holm et al. 2014). Micke et al. (2010) suggested that pelvic area measurement during selection may support the identification of heifers at an increased risk of dystocia. Apart from pelvic dimensions, the course of parturition is also positively correlated with rump slope, and a slightly sloping rump is most desirable (Gundelach et al. 2009).

The fact that breeding programs tend to focus on improving milk performance while ignoring functional parameters, including calving ease, makes it difficult to reduce dystocia (Gaafar et al. 2011, Nahkur et al. 2011). Over the past few decades, dual purpose (beef and dairy) cattle breeds have been gradually replaced by specialized dairy cattle breeds. For instance, Black-and-Whites (BW), which until recently had dominated in Europe, were replaced by Holstein-Friesians (HF). As a result, the incidence of dystocia has increased (Steinbock et al. 2003). The research hypothesis postulates that the increased incidence of difficult calving in HF heifers, as compared with BW heifers, results among other factors from changes in pelvic dimensions and rump angle, followed by changes in birth canal parameters. The aim of this study was to describe the differences in the structure of the bony pelvis between heifers of two breeds, and to assess their impact on calving ease. We want to check how the haefization process influenced the internal dimensions of the pelvic canal and its position in heifers.

Materials and Methods

Animals and treatments

The study was conducted in accordance with the Helsinki Declaration (Act of 15 January 2015 on the protection of animals used for scientific or educational purposes) the application was examined by the Local Ethical Committee in Olsztyn and received an exemption (Approval for exemption from permit of the Ethical Committee for the study, 29 July 2022). The experiment was conducted in four farms raising BW and HF cattle. Management, housing and reproduction conditions were similar in all herds. Cows were kept in the free-stall barns and milking took place in milking parlors. The average annual yield per cow was 7-9 thousand kg of milk. Heifer calves were raised in a semi-intensive system, and they were fed milk, milk replacer, hay, haylage and 1-2 kg of supplemental concentrate. After the rearing period, heifers grazed a pasture in summer, and they were fed ad libitum haylage supplemented with 1-2 kg of concentrate in winter. Heifers were inseminated upon achieving a body weight of 380-400 kg at 14-16 months of age. In-calf heifers were housed in group pens, and they received a total mixed ration (TMR) throughout the year; TMR was composed of haylage, maize silage, concentrate and a mineral premix. The course of parturition was evaluated in 317 heifers (BW-169 and HF-148) as 1) easy calving (EC), unassisted calving or assistance by one person with no use of mechanical calving aids; 2) difficult calving (DC), considerable difficulty with intervention of two persons or with the use of mechanical calving aids and veterinary assistance with or without surgical intervention. The stillbirth rate was estimated on a two-grade scale: 1) calf born alive, survived 24 hours after parturition; 2) stillborn calf or died within 24 hours after parturition. Placenta expulsion was classified as follows: 1) expelled within 12 hours after parturition; 2) expelled between 12 and 24 hours after parturition; 3) retained placenta. Calves were weighed at birth, within an accuracy of 0.1 kg. Between the 2nd and 3rd week postpartum (after the regression of perinatal edema), cows were weighed, held in a crush and measured. External body measurements and internal pelvic measurements were performed as described by Nogalski and Mordas (2012). Intrapelvic height and width were measured with the Rice pelvimeter (Lane Manufacturing, Denver, CO, USA) to the nearest 0.25 cm. Internal measurements of the pelvic canal were performed by an experienced person with many years of practice. Feces were manually removed from the rectum by the investigator, and the pelvimeter covered with gel was carefully introduced into the rectum. The pelvimeter was slowly advanced inside the rectum and carefully opened in a vertical plane to enable the measurement of the narrowest vertical distance between the ventral surface of the sacrum and the dorsal surface of the pubic symphysis (intrapelvic height) (Fig.1).

The pelvimeter was then closed, gently rotated 90°

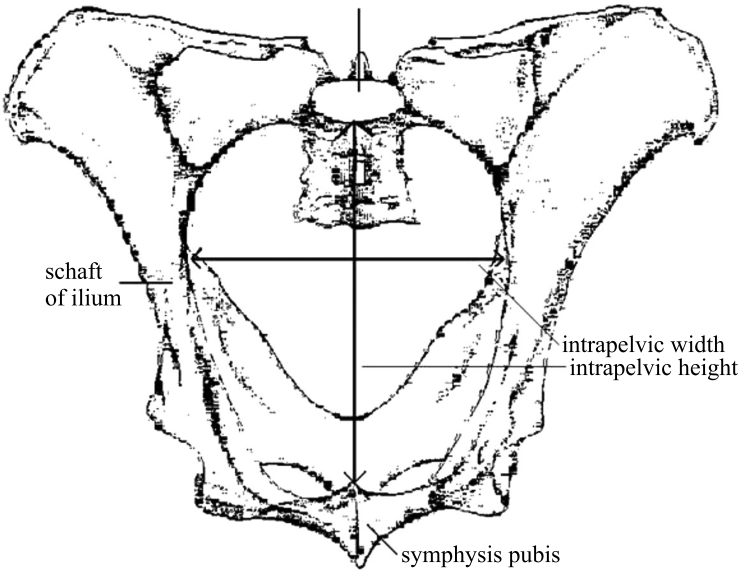

Figure 1. Inner dimensions of the pelvis

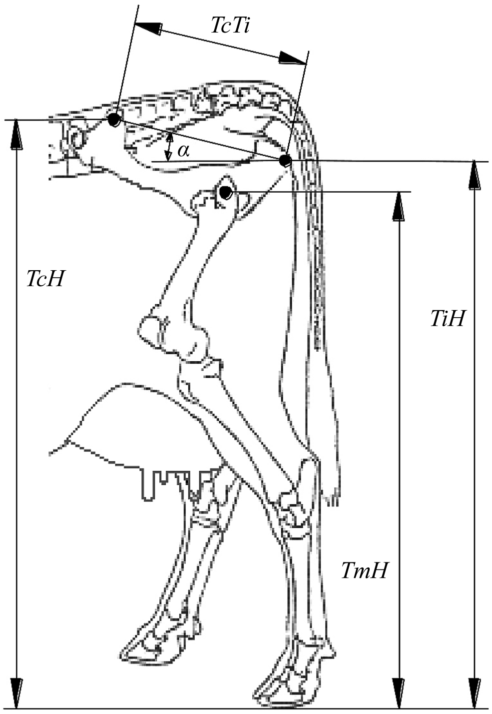

Fig. 2. Rump angle (RA)

TcH – height at hip (*tuber coxarum*),
TiH – height at pins (*tuber ischium*),
TmH – height at trochanter (t*rochanter major*),
TcTi – length of pelvic,
∝ – rump angle $\sin \alpha\ (RA) = \dfrac{TcH - TiH}{TcTi}$

and expanded to measure the widest horizontal distance between the left and right shafts of the ilium (intrapelvic width). Next, the closed pelvimeter was slowly removed from the rectum. The estimated intrapelvic area is calculated on the basis of height and width of the pelvic canal (i.e. vertical and horizontal measurements) (Kolkman et al. 2009). Rump angle was determined as the slope of the rump from the hip to the pin, taking into account pelvic length (Fig. 2). In order to reduce the stress of the animals during the measurements, they were given a Stressomix (FarmVet Poland). The preparation was administered with concentrate before the measurements.

Table 1. Traits affecting calving ease in Black-and-White (BW) and Holstein-Friesian (HF) heifers (Means ± SE).

Trait	BW n=169	HF n=148
Incidence of difficult calving (%)	13.1[B]	24.3[A]
Stillbirth rate (%)	4.6[B]	7.2[A]
Retained placenta (%)	6.4[b]	8.3[a]
Average age at calving (months)	28.5±0.24[A]	27.2±0.19[B]
Gestation length	278.1±0.36	278.7±0.38
Cow weight after calving (kg)	533.6±5.6[a]	511.6±3.84[b]
Calf weight at birth (CfW) (kg)		
bulls	39.2±0.34	40.1±0.38
heifers	37.0±0.31	37.9±0.33

SE – standard error; Means followed by different letters differ significantly: capital letters at p≤0.01; small letters at p≤0.05.

Statistical analysis

The results were analyzed using Statistica 13.3 software (Tibco Software Inc., Palo Alto, CA, USA). The effect of breed on calving ease, stillbirth and placenta expulsion was evaluated using the χ^2 test.

$$x^2 = \sum [\frac{(fi - fi)^2}{Fi}]$$

where:

fi – actual value

Fi – expected value

The effects of breed and course of parturition on the morphometric traits of cows were determined by the least squares method using the formula:

$$Yijk = \mu + Ai + Bj + (AB)ij + eijk$$

where: *Yijk* is the value of the analyzed parameter, μ is population mean, *Ai* is the effect of breed (1, 2), *Bj* is the effect of course of parturition (1, 2), *(AB)ij* is the interaction between breed and course of parturition, and *eijk* is random error.

Results

Both the course of parturition and perinatal mortality were affected (p<0.01) by breed (Table 1). The frequency of DC reached 24.3% in HF heifers and 13.1% in BW heifers. Stillbirths (stillborn calves and calves that died within 24 hours after parturition) accounted for 5.2% in HF calves and 3.6% in BW calves. The HF breed had a negative effect (p<0.05) on the percentage of retained placenta cases. In HF heifers, the average age at calving was 27.2 months, and they calved 1.3 months earlier (p<0.01) than BW heifers. BW heifers were heavier than HF heifers, by 22 kg on average (p<0.05).

During the internal measurements of the pelvic canal, no behavior deviating from normal behavioral patterns, indicative of stress or pain (groaning, muscle tremors, kicking at the abdomen), was observed in any of the animals. No complications (injuries, damage to the rectal mucosa, fertility disorders) related to the measurements were noted, either.

Relationships were found between the anatomical characteristics of heifers, their breed and the course of parturition (Table 2). Pelvic width at hips, measured externally, was higher (p<0.05) in BW heifers than in HF heifers, and in EC heifers than in DC heifers. Pelvic width at pins was significantly higher in EC heifers than in DC heifers. Pelvic length was higher (p<0.01) in HF heifers than in BW heifers. The internal dimensions of the bony pelvis were more desirable in BW and EC heifers (significant differences). Both intrapelvic width and height were greater in BW and EC heifers than in HF and DC heifers. An interaction between the analyzed factors was found for intrapelvic width. The difference in intrapelvic width between DC and EC groups was 0.5 cm in BW heifers and 0.2 cm in HF heifers. The differences in intrapelvic width and height resulted in significant differences in pelvic area, which was smaller in HF and DC heifers than in BW and EC heifers. The angle of the rump, defined as the slope of the rump from hips to pins, taking into account pelvic length, was higher (p<0.01) in BW heifers than in HF heifers, and in EC heifers than in DC heifers. Regardless of breed, the calves of DC heifers were heavier (p<0.01) than the calves of EC heifers.

Irrespective of breed, the ratio of calf birth weight to the dam's body weight at calving was lower (p<0.01) in the EC group than in the DC group. The value of the most important indicator of calving ease, i.e. the ratio of pelvic area to calf weight (PA/CfW), was higher (p<0.01) in BW heifers than in HF heifers, and in EC heifers than in DC heifers (Table 3). The difference in the PA/CfW ratio between EC and DC heifers reached 1.48 cm^2/kg among BW heifers and 0.69 cm^2/kg among HF heifers. The ratio of pelvic area to cow weight and ratio of pelvic area to height at withers were

Table 2. Body conformation traits of easy calving and difficult calving heifers of two genotypes.

Trait	Black-and-White		Holstein-Friesian		SE	Significance (P value)		
	easy calving (EC) n=137	difficult calving (DC) n=32	easy calving (EC) n=90	difficult calving (DC) n=58		G	CE	GxCE
Calf weight at birth (CfW) (kg)	36.8	41.1	37.7	40.1	0.26	0.381	0.000	0.234
External pelvic measurements								
Width at hips (cm)	54.1	53.1	53.2	52.6	0.16	0.039	0.027	0.518
Width at pins (cm)	19.5	18.8	19.2	19.1	0.08	0.936	0.033	0.051
Pelvic length (cm)	52.1	51.4	53.2	52.9	0.14	0.000	0.583	0.099
Rump angle (°)	10.2	9.4	7.6	6.7	0.27	0.000	0.006	0.062
Internal pelvic measurements								
Height of the pelvic canal (cm)	18.2	17.9	17.4	17.0	0.07	0.000	0.011	0.875
Width of the pelvic canal (cm)	17.6	17.1	17.1	16.9	0.06	0.014	0.018	0.041
Pelvic area (cm^2)	320.6	305.2	296.4	287.9	1.83	0.000	0.002	0.372

SE – standard error, G – significant effect of genotype (Black-and-White and Holstein-Friesian), CE – significant effect of calving ease (easy calving and difficult calving), GxCE – significant effect of interaction

Table 3. Indices determined based on the body measurements of heifers depending on genotype and course of parturition.

Traits	Black-White		Holstein-Friesian		SE	Significance (P value)		
	easy calving (EC)	difficult calving (DC)	easy calving (EC)	difficult calving (DC)		G	CE	GxCE
Ratio of calf weight to cow weight (%)	7.01	8.43	7.64	8.47	0.069	0.851	0.000	0.122
Ratio of pelvic area to calf weight (cm^2/kg)	8.72	7.24	7.86	7.17	0.069	0.001	0.000	0.124
Ratio of pelvic area to cow weight (cm^2/kg)	0.60	0.60	0.59	0.59	0.004	0.001	0.025	0.089
Ratio of pelvic area to height at withers (cm^2/cm)	2.44	2.32	2.19	2.10	0.014	0.000	0.000	0.563

SE – standard error, G – significant effect of genotype (Black-White – Holstein-Friesian), CE – significant effect of calving easy (easy calving – difficult calving), GxCE – significant effect of interaction

also higher in BW heifers than in HF heifers, and in EC heifers than in DC heifers.

Discussion

In the present study, the percentage of calving difficulty was high due to the fact that only heifers were analyzed and calving was classified as difficult when it required greater intervention than assistance by one person with no use of mechanical calving aids. In a study by Gaafar et al. (2011), only 7.7% of HF heifers experienced dystocia, and this value is three-fold lower than that noted in this experiment. Stillbirths, closely related to dystocia, were more frequently encountered in HF heifers than in BW heifers. In Germany, Gundelach et al. (2009) recorded 9.7% stillbirths in dairy herds, including 18.9% among heifers. In the USA, the proportion of stillbirths in Holstein-Friesians increased from 9.5% in 1985 to 13.2% in 1996 (Johanson et al. 2011) and still shows a rising tendency (Olson et al. 2009). In Sweden, Steinbock et al. (2003) estimated the incidence of calving difficulty at 8.3% in first parities, and reported that the stillbirth rate in Swedish Holstein heifers has increased over the past 10-15 years. During the same period, the import of HF semen from North America to Sweden and the proportion of HF genes in the population has increased dramatically. As a result, the breed has been gradually transformed from the Swedish Friesian to HF. A similar situation was observed in Poland where dual purpose (beef and dairy) BW cattle have been replaced by Holstein-Friesians via crossbreeding. This process has led to changes in the body conformation traits that significantly affect calving ease, which was also noted in the current study. Pelvic area, which is a particularly important parameter influencing calving difficulty, has decreased. In the present study, each kilogram of calf weight corresponded to 7.17 cm^2 (DC) and 7.86 cm^2 (EC) of pelvic area in HF heifers, and to 7.24 cm^2 (DC) and 8.72 cm^2 (EC) of pelvic area in BW heifers (Table 3). An analysis of the PA/CfW ratio revealed a difference of 1.09 cm^2 to the advantage of EC heifers, compared with DC heifers. Nogalski and Mordas (2012) demonstrated that in EC Jersey heifers, each kilogram of calf weight corresponded to 9.60 cm^2 of the birth canal, compared with only 6.65 cm^2 in HF heifers experiencing calving difficulty. Johanson and Berger (2003) found that in Holstein heifers, 11.0% decrease in the odds for dystocia was associated with 1 dm^2 increase in pelvic area. Gundelach et al. (2009), showed that the stillbirth rate was low in cows whose pelvic area at calving was minimum 320 cm^2. In the present study, the angle of the rump, defined as the slope of the rump from hips to pins, taking into account pelvic length, did not contribute to calving ease in HF heifers. A comparison of both breeds revealed that the values of intrapelvic height and width were 0.9 cm and 0.3 cm higher, respectively, in BW heifers. This indicates that increased intrapelvic height contributed most to increased pelvic area, as confirmed by a higher rump angle in BW heifers. It appears that the above changes could result from long-term selection for high box-shaped udders extending forward and well backward in Holstein-Friesians. The udder is suspended by ligaments attached at the pubic symphysis and the ischium. A long and level rump supports udder development and its firm attachment to the abdominal wall. Improper selection has contributed to calving difficulty; in contrast, calving ease has evolved over thousands of years in wild populations. According to Nahkur et al. (2011), who compared the pelvises of Estonian Native Breed and Estonian Holstein (EHF) cows, the increased incidence of dystocia in EHF cows is the consequence of changes in bony pelvis parameters, in particular the fact that the pelvic aperture narrows ventrally and is trapezoid-shaped with rounded angles. In the current study, the size of the pelvic canal decreased in HF heifers, relative to BW heifers, mostly due to its lower height. Tyczka (1998) reported that intrapelvic height was positively correlated with rump angle. In this experiment, rump angle slope was greater in EC heifers that were characterized by a greater vertical diameter than DC heifers. In the present study, the ratio of pelvic area to height at withers was 0.24 cm^2/cm higher in BW heifers, compared with HF heifers (taking into account mean values for EC and DC groups), which implies that during selection, the body size of HF cattle increased in terms of height rather than pelvic parameters (Table 3).

Pelvic measurements with the Rica pelvimeter are easy to perform and safe for animals (Nogalski and Mordas 2012, Holm et al. 2014). Holm et al. (2014) measured 484 one-year-old heifers and found that measuring the size of the birth canal, along with other body parameters, can significantly reduce the occurrence of difficult parturitions by eliminating heifers with narrow birth canals. Measurements with a pelvimeter can also be used to determine the spatial relations in the pelvic canals of heifers, and predict the probability of calving difficulty (Bila et al. 2021, Maeda et al. 2022). In none of these experiments (Nahkur et al. 2011, Nogalski and Mordas 2012, Holm et al. 2014, Bila et al. 2021, Maeda et al. 2022), pelvic measurements with the Rica pelvimeter caused pain, suffering or stress in animals, which indicates that they can be considered a useful, reliable and safe management tool.

Conclusions

The replacement of the dual-purpose BW breed with the HF breed negatively affected the calving ease of heifers due to changes in the structure of their pelvises. Intrapelvic height and rump angle decreased in HF heifers. High variation in the internal pelvic dimensions in HF heifers indicates that the incidence of dystocia can be reduced through selection for a larger pelvic size and the optimal rump angle. Follow-up research is needed to examine the effects of other factors, in combination with the body conformation traits of heifers, on calving ease.

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